Structure of isomeric states in ^{66}As and ^{67}As

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Abstract

Strong residual correlations between neutrons and protons in $N \approx Z$ systems can lead to unusual structure. Using the spherical shell model, we show that a low-excitation shape isomer can occur in the odd-odd $N = Z$ nucleus ^{66}As. This extends the picture of shape coexistence beyond even-even nuclei. Furthermore, it is demonstrated that in ^{66}As and in the $N = Z + 1$ nucleus ^{67}As, a new type of isomer, which we term j-isomer, can be formed. The underlying mechanism for the isomerism formation is structure change in the isomeric states, which involves either an alignment of a neutron-proton pair from the high-j intruder orbitals, or a simultaneous occupation of these neutron and proton high-j orbitals.

Key words: isomeric states, $N \approx Z$ nuclei, shell model
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Nuclear structure study near the $N = Z$ line from nickel to $A \sim 100$ nuclei is one of the current research topics in nuclear physics. There are at least two reasons why one is interested in these nuclei. First, this region is characterized by rapid shape change [1] from nucleus to nucleus, exhibiting abundance of interesting structure. The occurrence of the rich phenomena, with some of their origins still unknown, is unique to this mass region. It is likely due to the occupancy of the same orbitals by neutrons and protons, which leads to strong residual neutron-proton correlations. Second, it is anticipated [2] that the unique structure may have implications in the understanding of nucleosynthesis. It has been suggested that the proton-rich nuclei near the $N = Z$ line are synthesized in the rapid-proton capture process (the rp-process) [3]

under appropriate astrophysical conditions, such as in the X-ray burst environment. The rp-process creates nuclei far beyond ^{56}Ni all the way to the heavy proton-rich regions of the chart of nuclides. However, current network simulations for the rp-process may contain large uncertainties because of the lack of information on the structure near the $N = Z$ line.

Among the variety of structure discussed in this mass region, nuclear isomer is probably the least understood one. Isomeric states are excited metastable states, which are formed only in a limited number of nuclei depending on the detailed shell structure of the neutron and proton orbitals. Often discussed in the literature are three mechanisms [4] leading to nuclear isomerism. It is difficult for an isomeric state to change its shape to match the states to which it is decaying, or to change its spin, or to change its spin orientation relative to an axis of symmetry. These correspond to shape isomers, spin traps, and K-isomers, respectively. In any of these cases, γ-decay to the ground state is strongly hindered, either by an energy barrier or by the selection rules of electromagnetic transition. Therefore, isomer lifetimes can be remarkably long. As recently studied examples in the $A = 60 - 100$ nuclei, a $J^\pi = 0^+$ excited state in ^{72}Kr has been found as a shape isomer [5], a 12^+ state in ^{98}Cd as a spin trap [6], and a 9^+ excited bandhead in ^{70}Br, possibly as a K-isomer [7].

Experimental study of excited states in $N \approx Z$ nuclei is a rather challenging problem. Despite the difficulties, information about isomeric states has been gathered in recent years. The nucleus ^{66}As has aroused a special interest in the study of odd-odd $N = Z$ nuclei since the discovery of two isomeric states, the $J^\pi = 5^+$ one at 1.357 MeV and the 9^+ one at 3.024 MeV [8,9]. In the lighter odd-odd $N = Z$ nucleus ^{62}Ga, an isomeric state with 3^+ at a much lower excitation 0.817 MeV has been known [10,11]. It has also been reported that the odd-mass nucleus ^{67}As has an isomeric state with $9/2^+$ [12]. On the theoretical side, some of these nuclei have been investigated by different theoretical models, such as the shell model [10,11], interacting boson model [13], and a deformed shell model [14]. However, the question of why the above mentioned states become isomeric and what the nature of the isomerism is has not been thoroughly addressed.

In this Letter, we investigate the structure of isomeric states in odd-odd $N = Z$ nucleus ^{66}As and in adjacent odd-mass nucleus ^{67}As. The calculation is performed by using the spherical shell model. Our discussion on the results will focus on those states that have notably small electromagnetic transition probabilities to the low-lying states. Analysis shows that there are essentially two different types of isomers entering into discussion. Due to the fact that prolate and oblate shapes can coexist at the low excitation region, a shape isomer is predicted in ^{66}As. The other type of isomer is related to a suppressed decay between structures based on the high-j $g_{9/2}$ intruder orbital and the pf-shell configurations.

We start with a general form of the extended $P+QQ$ Hamiltonian which is composed of the single-particle energies, $T=0$ monopole field, monopole corrections, pairing forces with $J=0$ and $J=2$, quadrupole-quadrupole (QQ) force and octupole-octupole (OO) force [15,16]:

$$\begin{aligned} H &= H_{\rm sp} + H_{\pi\nu}^{T=0} + H_{\rm mc} + H_{P_0} + H_{P_2} + H_{QQ} + H_{OO} \\ &= \sum_{\alpha} \varepsilon_a c_\alpha^\dagger c_\alpha - k^0 \sum_{a\le b} \sum_{JM} A^\dagger_{JM00}(ab) A_{JM00}(ab) \\ &+ \sum_{a\le b} \sum_{T} \Delta k_{\rm mc}^{T}(ab) \sum_{JMK} A^\dagger_{JMTK}(ab) A_{JMTK}(ab) \\ &- \sum_{J=0,2} \frac{1}{2} g_J \sum_{M\kappa} P^\dagger_{JM1\kappa} P_{JM1\kappa} \\ &- \frac{1}{2}\chi_2 \sum_M :Q^\dagger_{2M} Q_{2M}: - \frac{1}{2}\chi_3 \sum_M :O^\dagger_{3M} O_{3M}: . \end{aligned} \tag{1}$$

This isospin invariant Hamiltonian is diagonalized in the chosen model space based on a spherical basis [17]. In the present work, we employ the $pf_{5/2}g_{9/2}$ model space. This shell model has recently proven to be rather successful in describing nuclear shapes, energy levels, and the band-crossing phenomenon in Ge and Zn isotopes, as well as in ^{68}Se [18,19,20]. For the interaction strengths, we adopt the same (A-dependent) parameters as those employed in Ref. [20], except that we add the following monopole terms:

$$\Delta k_{\rm mc}^{T=0}(a, g_{9/2}) = -0.18 \text{ MeV}, \quad a = p_{3/2}, f_{5/2}, p_{1/2}. \tag{2}$$

These additional monopole terms have an effect of lowering the $g_{9/2}$ orbital, which is needed for obtaining correct positions of the 9_1^+ state and the higher spin states relative to the 7_1^+ state in ^{66}As. Such additional monopole terms are found necessary also for other odd-odd $N=Z$ nuclei in our calculations, though there remains a question why odd-odd $N=Z$ nuclei require these terms. The $T=0$ monopole field $H_{\pi\nu}^{T=0}$ affects significantly the relative energy between the $T=1$ and $T=0$ states in odd-odd $N=Z$ nuclei [15]. We have determined the strength k^0 to be $1.2(64/A)$, which roughly reproduces the excitation energies of the 7_1^+ and 9_1^+ states in ^{66}As. The effective charges used in the calculation are $e_{\rm eff}^{\pi} = 1.5e$ and $e_{\rm eff}^{\nu} = 0.5e$.

The calculated energy levels for ^{66}As are compared with the experimental data [9] in Fig. 1. As one can see, our calculation produces a level scheme similar to the observed one [9]. We correctly obtain the $T=1$ ground state band (the 0^+-2^+-4^+ sequence) and the 1_1^+ state as the lowest state of $T=0$. We notice that in ^{66}As, the experimental $T=0$, 1^+ state is marked as uncertain [9], and in the heavier odd-odd $N=Z$ nuclei ^{70}Br [7] and ^{74}Rb [21], such a 1^+ state is experimentally missing. Above the 1_1^+ state, there are the first $J=3$

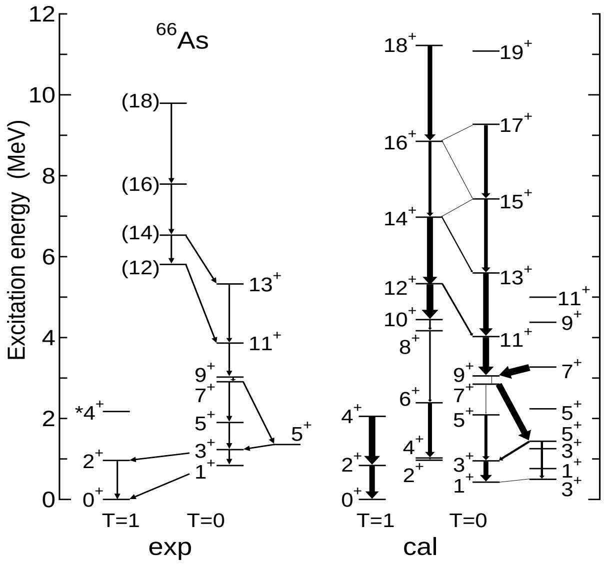

Fig. 1. Experimental and calculated energy levels in ^{66}As. The arrows between the experimental states (exp) indicate the observed electromagnetic transitions in Ref. [9], and widths of the arrows between the calculated states (cal) denote relative values of the calculated $B(E2)$. The experimental energy of the $T = 1$, 4_1^+ state is taken from ^{66}Ge.

state 3_1^+ and the first $J = 5$ state 5_1^+. Interestingly enough, the calculated $E2$ transition strength $B(E2 : 3_1^+ \rightarrow 1_1^+)$ is only 1.3 Weisskopf unit (W.u.), which is much smaller than the value 16 W.u. for $B(E2 : 3_2^+ \rightarrow 1_1^+)$. The calculated $B(E2 : 5_1^+ \rightarrow 3_2^+)$ is also smaller than $B(E2 : 5_2^+ \rightarrow 3_2^+)$. We are thus compelled to conclude that the 3_2^+ and 5_2^+ states belong to the same collective sequence with the 1_1^+ state, which resembles the observed band of $T = 0$ [9], but the 3_1^+ and 5_1^+ states do not. Whereas our calculated 5_1^+ state may correspond to the observed 5^+ isomeric state [8] (see discussions below), the predicted 3_1^+ state seems to be missing in the experiment.

In order to understand the structure of these states, we study the wavefunctions by calculating expectation values of proton and neutron number operators in the four orbitals, as well as those of spin and isospin for nucleons from the subspaces $pf = (p_{3/2}, f_{5/2}, p_{1/2})$ and $g_{9/2}$. To facilitate the discussion, we denote the former quantity by $(\langle n_a^\pi \rangle, \langle n_a^\nu \rangle)$, and the latter by (J_i, T_i), with $i = pf$ or $g_{9/2}$. The expectation values of spin and isospin, J_i and T_i, are respectively evaluated from $J_i = [\langle (\hat{j}_i)^2 \rangle + 1/4]^{1/2} - 1/2$ and $T_i = [\langle (\hat{t}_i)^2 \rangle + 1/4]^{1/2} - 1/2$, where $\hat{j}_i$ is the spin operator and $\hat{t}_i$ the isospin operator. Table 1 shows these expectation values and the calculated spectroscopic Q-moment, defined as $Q = \sqrt{16\pi/5} \sum_{\tau=\pi,\nu} e_{\text{eff}}^\tau \langle r^2 Y_{20} \rangle_\tau$.

From Table 1, it is interesting to observe that the sign of spectroscopic Q-moment in 3_1^+ state is opposite to those of all other states. Hence the shape of the 3_1^+ state is predicted to be oblate, in contrast to the prolate shape for

other states. This conclusion has also been confirmed by the potential energy surface for ^{66}As with the same method as used in Ref. [19]. In addition to the rather small $B(E2 : 3_1^+ \to 1_1^+)$, the calculated energy difference between the 3_1^+ and the lowest $T = 0$ state 1_1^+ is only about 0.07 MeV. Thus the present model calculation predicts a long-lived 3^+ shape isomer.

An isomeric 3^+ state has been found in the lighter odd-odd $N = Z$ nucleus ^{62}Ga [10,11]. According to Ref. [11], the isomeric nature of this state simply arises from the small transition energy. The measured half-life is $T_{1/2} = 4.9(^{14}_{13})$ ns and the corresponding $B(E2 : 3_1^+ \to 1_1^+)$ value is $\sim$ 13 W.u. To compare with these data in ^{62}Ga, we have carried out a shell model calculation. Our model reproduces considerably well the observed energy levels in ^{62}Ga [11]. The $B(E2 : 3_1^+ \to 1_1^+)$ value is calculated to be 8.7 W.u., which is comparable to those from other shell model calculations [10,11]. However, our calculation suggests that the isomeric 3^+ state in ^{62}Ga belongs to the same $T = 0$ band with the 1^+ state as the bandhead, and the calculated spectroscopic Q-moment for the 3^+ state has the same sign as the other states.

Thus, unlike the 3^+ isomer in ^{62}Ga, the lowest $T = 0$, 3^+ state in ^{66}As is a shape isomer in nature. This provides an example in odd-odd $N = Z$ nuclei that a low-lying state corresponding to oblate shape coexists with those having prolate shape. Shape coexistence phenomenon, i.e. occurrence of two or more stable shapes in a nucleus at comparable excitation energies, has been known in the neighboring even-even $N = Z$ nuclei. In ^{72}Kr, the excited 0^+ bandhead state at 0.671 MeV was identified as a shape isomer with lifetime 38 ns [5].

Table 1
Expectation values of nucleon numbers in the four orbitals, those of spin and isospin of nucleons in the subspaces $pf = (p_{3/2}, f_{5/2}, p_{1/2})$ and $g_{9/2}$, and calculated spectroscopic Q-moments (in e fm^2), for the $T = 0$ states in ^{66}As.

	$\langle n_a^\pi \rangle = \langle n_a^\nu \rangle$				J_i, T_i				
$T = 0$	$p_{3/2}$	$f_{5/2}$	$p_{1/2}$	$g_{9/2}$	J_{pf}	T_{pf}	$J_{g9/2}$	$T_{g9/2}$	Q
1_1^+	2.13	2.16	0.52	0.19	1.30	0.22	0.67	0.22	-21.0
3_2^+	2.07	2.23	0.54	0.16	3.06	0.19	0.64	0.19	-26.3
5_2^+	2.04	2.14	0.67	0.15	4.97	0.18	0.64	0.18	-30.9
7_1^+	1.97	2.36	0.53	0.14	6.90	0.17	0.74	0.17	-28.8
3_1^+	2.12	2.19	0.52	0.18	2.96	0.22	0.72	0.22	+46.2
5_1^+	1.99	2.33	0.55	0.13	4.97	0.17	0.58	0.17	-15.0
9_1^+	1.59	1.82	0.55	1.04	1.77	0.07	8.93	0.07	-84.7
11_1^+	1.61	1.75	0.61	1.03	2.74	0.06	8.95	0.06	-90.1
9_2^+	1.63	1.66	0.58	1.14	2.77	0.90	7.77	0.81	-69.1

A similar shape isomer in ^{68}Se has been predicted [2,22] to exist, awaiting experimental confirmation. Thus, our results here reinforce the early claim [1] about violent shape change in this mass region. We may further speculate that the non-observation of the anticipated $T = 0$ bandhead 1^+ state in ^{70}Br and ^{74}Rb may imply a highly mixed structure in this state due to the shape coexistence nature, thus suppressing the decay.

In Ref. [8], an isomeric state 5_1^+ at 1.357 MeV with half-life $T_{1/2} = 1.1(1)$ μs was reported, which was interpreted based on a non-collective picture. Our calculation reproduces a decay scheme similar to the observed one. However, the calculated value 7.4 W.u. for $B(E2 : 5_1^+ \rightarrow 3_2^+)$ is about twenty times larger than the experimental value 0.34(9) W.u. Thus our calculation can not explain the isomerism of the experimental 5_1^+ state. The nucleon occupation numbers $\langle n_a \rangle$ in Table 1 show that all the low-lying states below the 9_1^+ one contain a strong configuration mixing in the pf subspace. In this sense, the 5_1^+ state is regarded as a collective state. Thus in our picture, a long half-life of the 5_1^+ state should be attributed to its different collective structure from other lower-lying states to which it decays. Our calculated Q-moments suggest that the 5_1^+ state has indeed a different structure from the lower-lying states of the $T = 0$. However, the difference seems to be insufficient to explain the 5_1^+ isomerism found in experiment. We leave this as an open question.

Now we move our discussion to the $J^\pi = 9^+$ isomeric state discovered in Refs. [8,9]. This state has a long half-life $T_{1/2} = 8.2(5)$ μs, and the measured $E2$ transition to the 7^+ state is only 0.044(6) W.u. [8]. Our calculated $B(E2)$ value for this transition is 0.023 W.u., which reproduces well the observed one. To see what causes this state to have such a long lifetime, let us study the quantities listed in Table 1. The calculated spectroscopic Q-moment for the 9_1^+ state shows a very different value from the other lower-lying states, indicating a different structure. The change in structure in the 9_1^+ state is caused by rotational alignment of $g_{9/2}$ particles. From Table 1, it can be clearly seen that $\langle n^\pi_{g9/2} \rangle = \langle n^\nu_{g9/2} \rangle \approx 1$, $J_{g9/2} \approx 9$ and $T_{g9/2} \approx 0$ for the states 9_1^+ and 11_1^+, indicating a complete $g_{9/2}$ one-proton-one-neutron ($1p1n$) alignment. The $T = 0$, $1p1n$ alignment in even-even nuclei has been discussed in Refs. [18,20]. When comparing the occupation numbers $\langle n_a \rangle$ in ^{64}Ge and ^{66}As, we find that a state with a pair alignment in ^{66}As may be symbolically denoted as ^{64}Ge$\otimes(g^\pi_{9/2} g^\nu_{9/2})$. In the language of the projected shell model [23], this is a two-quasiparticle configuration. In contrast, the states below the 9_1^+ state comprise nucleons mainly from the pf shell. It is then clear that the electromagnetic transitions to a state below 9_1^+ is strongly retarded by single-particle operators. Thus, the isomeric nature of the 9_1^+ state is attributed to the fact that the 9_1^+ state abruptly changes the structure by breaking a $T = 0$, $1p1n$ pair from the $g_{9/2}$ orbitals and aligning them with the rotational axis.

The above analysis actually suggests a new class of isomers, which may occur

in $N \approx Z$ systems only. An isomeric state may be formed at a high spin when a rotational alignment of a pair is completed in this state. The involved pair consists of one proton and one neutron from the high-j intruder orbitals ($g_{9/2}$ in our example here), which have distinct properties from the nearby normal parity orbitals. The significant structure change in the wavefunctions before and after the alignment suppresses electromagnetic transitions, resulting in a long-lived state. This conclusion is robust because even if we switch off the monopole corrections in Eq. (2), the $B(E2 : 9_1^+ \rightarrow 7_1^+)$ value still remains very small. The suppression of transitions is not due to existence of an energy barrier or violation of the selection rules. It is thus obvious that this type of isomer does not belong to any of the three isomer classes already discussed in the literature [4]. We may term it *j-isomer* since the underlying mechanism leading to it is the presence of significant components of the high-j intruder states in the wavefunctions. The observed 8.2 μs, 9^+ state in Refs. [8,9] is an example of a j-isomer.

In our calculation, there is the second 9^+ state lying slightly above 4 MeV. As can be seen from Table 1, the structure of this state is again very different from the others. The wavefunction of this 9_2^+ state has a large component of a $T = 1$, $g^{\pi}_{9/2}g^{\nu}_{9/2}$ aligned pair with $J \approx 8$, and the core excluding the $g_{9/2}$ nucleons has $J \approx 2.8$ and $T = 0.9$. The calculated $B(E2)$ values to the lower-lying states 7_1^+, 9_1^+, and 11_1^+ do not exceed 0.7 W.u. Therefore, the 9_2^+ state possibly has a long lifetime.

The odd-proton $N = Z + 1$ nucleus ^{67}As has a known isomeric state $9/2^+$ at 1.422 MeV with $T_{1/2} = 12(2)$ ns. To study the structure of this state,

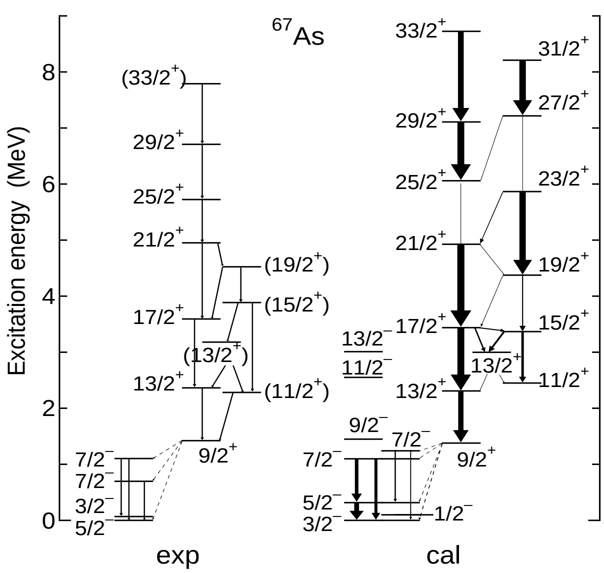

Fig. 2. Experimental and calculated energy levels in ^{67}As. Widths of the arrows between the calculated states (cal) denote relative values of the calculated $B(E2)$ (solid lines) and $B(E3)$ (dotted lines).

we have performed shell model calculations for ^{67}As. Energy levels obtained by the calculation are compared with the experimental ones [12] in Fig. 2. Again our calculation reproduces well the experimental level scheme. The only disagreement with data is the ground state spin. While data suggested that the ground state has the spin $I^\pi = 5/2^-$, our calculation obtained a $3/2^-$ state as the lowest state in ^{67}As. Repeated calculations by changing the parameters within the extended $P + QQ$ Hamiltonian have not succeeded to get a $5/2^-$ ground state. We notice that ^{65}Ge has the ground state $3/2^-$, which is correctly reproduced by our calculations. Presently, we can not explain why ^{65}Ge with 33 neutrons has the ground state $3/2^-$, while ^{67}As with 33 protons should have the ground state $5/2^-$.

Further inspection of the wavefunctions shows that, similar to its even-even and odd-odd neighbors, the low-lying states in this odd-proton nucleus are also characterized by shape coexistence. We have calculated for ^{67}As the expectation values $\langle n_a^\pi \rangle$ and $\langle n_a^\nu \rangle$, as well as J_i and T_i. Part of the results is shown in Table 2. The numbers indicate a strong configuration mixing in the pf subspace as found in ^{66}As. Protons and neutrons appear to be excited from the $p_{3/2}$ to the $f_{5/2}$ orbital in the $5/2_1^-$, $3/2_1^-$, and $7/2_1^-$ states. This effect lowers the $3/2_1^-$ state in the calculation. The $5/2_1^-$ and $3/2_1^-$ states are not simply single-particle-like states. The calculated spectroscopic Q-moment suggests an oblate shape for $3/2^-$ but a prolate shape for $5/2^-$. In addition, the present model predicts a very low-lying $1/2^-$ state. The $1/2^-$ state actually becomes the ground state in the neighboring nucleus ^{67}Ge, which is correctly reproduced by our model [20]. We can thus conclude that our model reproduces

Table 2
Expectation values of proton and neutron numbers in the four orbitals, calculated for those low-lying states in ^{67}As. Calculated spectroscopic Q-moments (in e fm^2) are also tabulated.

	$\langle n_a^\pi \rangle$				$\langle n_a^\nu \rangle$				
^{67}As	$p_{3/2}$	$f_{5/2}$	$p_{1/2}$	$g_{9/2}$	$p_{3/2}$	$f_{5/2}$	$p_{1/2}$	$g_{9/2}$	Q
$1/2_1^-$	1.99	2.15	0.72	0.15	2.33	2.30	1.19	0.17	1.1
$3/2_1^-$	2.17	2.12	0.54	0.17	2.48	2.60	0.73	0.19	23.9
$5/2_1^-$	2.06	2.13	0.68	0.13	2.36	2.74	0.74	0.17	-13.8
$7/2_1^-$	2.04	2.19	0.62	0.15	2.36	2.78	0.68	0.18	-24.2
$7/2_2^-$	2.16	1.66	1.00	0.18	2.33	2.35	1.12	0.20	-1.5
$9/2_1^+$	1.69	1.93	0.65	0.73	2.26	2.43	0.81	0.51	-57.9
$13/2_1^+$	1.78	1.88	0.62	0.72	2.22	2.62	0.63	0.53	-57.8
$11/2_1^+$	1.75	1.77	0.75	0.73	2.19	2.34	0.88	0.59	-51.6
$15/2_1^+$	1.85	1.90	0.61	0.64	2.14	2.52	0.66	0.69	-56.4

considerably well the low-lying negative-parity and the positive-parity states.

The long life of the $9/2_1^+$ state corresponds to suppressed electromagnetic transitions to the lower negative-parity states. Calculated reduced $E3$ transition strengths from $9/2_1^+$ to the $5/2_1^-$, $3/2_1^-$, $7/2_1^-$, and $7/2_2^-$ states are 0.057, 0.074, 0.001, and 0.010 W.u., respectively. These rather small $B(E3)$ values are consistent with the long life of the $9/2_1^+$ state. Naively, one may think of a simple picture for the $9/2_1^+$ state that the last proton occupies the $g_{9/2}$ orbital. However, the proton and neutron occupation numbers in Table 2 indicate a completely different structure. The neutron occupation number $\langle n_a^\nu \rangle$ in the $g_{9/2}$ orbital is unexpectedly large. The expectation values of spin and isospin of nucleons in the $g_{9/2}$ orbital, $J_{g9/2}$ and $T_{g9/2}$, are 4.54 and 0.53, respectively. These values, $\langle n_a^\pi \rangle = 0.73$, $\langle n_a^\nu \rangle = 0.51$, $J_{g9/2} \approx 9/2$, and $T_{g9/2} \approx 1/2$, suggest two dominant configurations: one has a proton (and probably a fraction of $J = 0$ neutron pair) in the $g_{9/2}$ orbital and the other has a neutron (and probably a fraction of $J = 0$ proton pair) in the $g_{9/2}$ orbital. The large components of the configurations may be symbolically expressed as a mixture of $^{66}\mathrm{Ge} \otimes g_{9/2}^\pi$ and $^{66}\mathrm{As} \otimes g_{9/2}^\nu$. To have these configurations, the neutron $g_{9/2}$ and the proton $g_{9/2}$ orbitals must be occupied simultaneously. Simultaneous occupation of the same orbital by protons and neutrons is certainly the unique property for $N \approx Z$ nuclei. On the other hand, the negative-parity states below the $9/2_1^+$ state are collective states with strongly mixed configurations in the pf subspace. The electromagnetic transitions are therefore strongly hindered by single-particle operators.

In conclusion, to study the structure of isomeric states, we have calculated the odd-odd $N = Z$ nucleus ^{66}As and the odd-proton $N = Z + 1$ nucleus ^{67}As, in the framework of the spherical shell model. By using the extended $P + QQ$ Hamiltonian, we are able to reproduce the level schemes for these two isotopes. In ^{66}As, a $T = 0$, 3^+ state has been predicted at about 1 MeV. We suggest that this is a shape isomer, and once confirmed, it may represent the first example of a shape isomer in an odd-odd nucleus in this mass region. The occurrence of a shape isomer in ^{66}As supports the picture of prolate-oblate shape coexistence at low-excitations, and may provide a clue to the puzzle of non-observation of the anticipated $T = 0$ bandhead state in some heavier odd-odd $N = Z$ nuclei. The structure of the experimentally known isomeric state 9^+ in ^{66}As and $9/2^+$ in ^{67}As have been studied and termed j-isomers, which, unlike the three well-known classes of isomers, are unique to $N \approx Z$ nuclei. The formation of j-isomer requires either an alignment of a neutron-proton pair from the high-j intruder orbitals (in ^{66}As), or a simultaneous occupation of these neutron and proton high-j orbitals (in ^{67}As).

To go to heavier, deformed mass region with $A > 70$, one may refer to shell models based on a deformed basis, such as the projected shell model [23]. From the theoretical point of view, it would be interesting to compare, while

employing the same Hamiltonian, the results of both types of shell models constructed in a spherical or in a deformed basis. The nuclei discussed here are perfect cases for a comparison. Work along these lines is in progress.

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